A NEOGENE SECTION, NORTHEASTERN SAN CLEMENTE ISLAND, CALIFORNIA[1]

By TAKEO SUSUKI[2] AND CAROL J. STADUM[3]

ABSTRACT: A discontinuous section of Miocene, Pliocene, Pleistocene, and Recent sediments overlies rhyolite 0.9 to 2.5 kilometers south of the Naval Ordinance Test Station Pier in the area of Randall Blockhouse, northeastern San Clemente Island, Los Angeles County, California. Poorly consolidated orange sandstone containing the Miocene mollusk *Pecten (Amussiopecten) lompocensis* Arnold and marine limestone lenses, grades upward into diatomaceous shale equivalent to the Miocene Monterey Formation. Unconformably overlying the Miocene units are Pliocene bioclastic sediments containing the mollusks *(Pecten) (P.) bellus* (Conrad) and *Pecten (Patinopecten) healeyi sanclementensis* n. subsp. Isolated outcrops of Pleistocene sand, containing a molluscan fauna, correlate with the Palos Verdes Sand of the Los Angeles Basin. An occurrence of a desmostylid tooth is reported and illustrated.

INTRODUCTION

San Clemente Island, the southernmost Channel Island off the southern California coast, is approximately 96 km south and west of Long Beach. (Figs. 1,2) The elongate island, extending northwest to southeast, is 35 km long and 2 km to 6.4 km wide. Sediments cover the slightly tilted and gently domed block, which is composed of lava flows, tuffs, and breccias that have been dated at about 15.7 million years (Merifield and others 1971). More than twenty marine terraces are exposed on the western slope of the island, while the eastern flank rises steeply from the northwest trending San Clemente fault.

During a visit to the island in April, 1975, an outcrop of Pliocene biosediments was located in a discontinuous Neogene section by the junior author. The occurrence of these strata was reported by Stadum and Susuki (1976) as containing mullusks and brachiopods, interbedded in sediments composed predominantly of bryozoans, foraminifers and echinoid spines of Pliocene age and the authors' findings were subsequently confirmed in a later publication by Vedder and Moore (1976). The only Channel Island known to contain similar age strata is Santa Cruz Island (Weaver and Myer 1969). An extensive field investigation was undertaken in July and November, 1975, to determine the areal extent of the discontinuous Neogene section. The Neogene

---

[1] REVIEW COMMITTEE FOR THIS CONTRIBUTION
WARREN O. ADDICOTT
JERE H. LIPPS
EDWARD C. WILSON

[2] Research Associate in Invertebrate Paleontology, Natural History Museum of Los Angeles County, and Department of Geology, University of California, Los Angeles, California, 90024.

[3] Huntington Beach High School, 1905 Main Street, Huntington Beach, California, 92648.

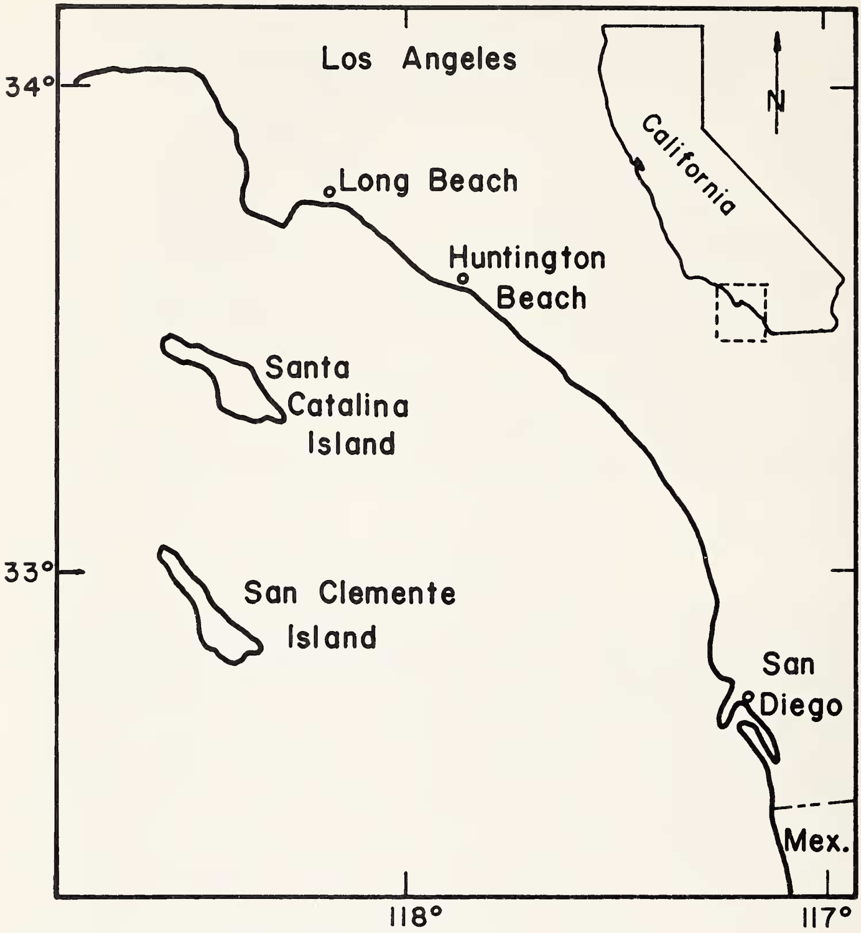


FIGURE 1. Index map showing general location of San Clemente Island.

marine mollusks from northeast San Clemente Island are summarized and a new Pliocene subspecies is described and illustrated.

The specimens are deposited in the paleontology collection, Department of Geology, University of California, Los Angeles.

PREVIOUS GEOLOGIC INVESTIGATIONS

The earliest publication to describe the San Clemente Island lithology was Cooper (1865). This report stated that the "island form is that of a terraced table" and that the rocks are composed almost entirely of basalt. He implied that the scarcity of fossils was apparently due to lack of marine sediments. Lawson (1893) discussed the physiography in detail and mentioned fossiliferous white limestone which, he thought, was equivalent to the mainland Miocene coastal deposits. Smith (1898) recognized that a portion of the island was composed of Miocene sandstone, shale, and limestone with overlying sediments which were post-Pliocene in Age. Olmsted (1958) distinquished the lower sedimentary unit as middle Miocene and the unconsolidated sand deposits as Pleistocene (?).

Mitchell and Lipps (1965) collected numerous Miocene marine vertebrates, pelecypods, algae, and microörganisms from the Chalk Canyon area (Horse Cove) and two mid-island basins. They stated that an interval of geologic history "from about the end of the middle Miocene to about 500,000 years or so ago" is missing. Oceanographic surveys by Ridlon (1968; 1969; 1972) found middle Miocene sedimentary rocks, post-Miocene sediments of undetermined age, and Holocene surficial sediments offshore near Eel Point. Merifield and others (1971) emphasized the petrography and structure and volcanic rocks on the central part of the island, and noted the presence of Miocene sediments and Quaternary beach sand. Most recently, Vedder and others (1975), and Vedder and Moore (1976) discussed Miocene and Pliocene biostratigraphy and paleontology of the island. These publications did not include the Neogene sediments south of Randall Blockhouse in sections RS-2 and RS-3 of this paper.

STRATIGRAPHY

INTRODUCTION

The authors have used abbreviations for four sections of Neogene sediments exposed near Randall Blockhouse, an observation structure and lighthouse about 900 m south of NOTS (Naval Ordinance Test Station) Pier. Neogene sediments overlie rhyolite and are exposed in gullies northwest, west and south of Randall Blockhouse. The letters "RS" refer to "Randall Section", with the number indicating the location of outcrop (Fig. 3).

RS-1 = Pliocene sediments in roadcut above Randall Blockhouse and a ravine just to the west of the roadcut. (includes localities 6316, 6318 and 6320).

RS-2 = Miocene, Pliocene and Pleistocene in a steep gully about 213 m south of Randall Blockhouse. (includes localities 6321 and 6327).

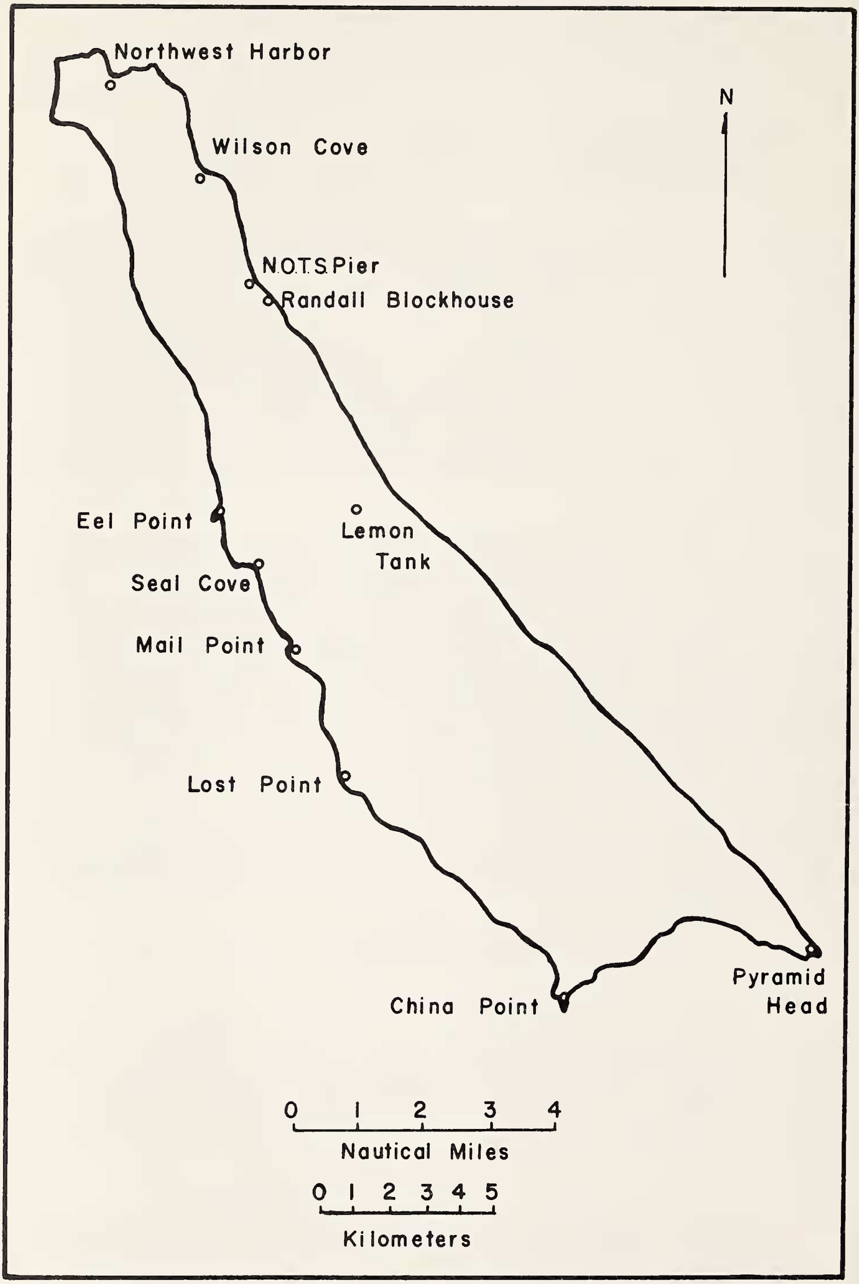


FIGURE 2. Index map of San Clemente Island showing some of the prominent landmarks.

RS-3 = Miocene beds about 1525 m southeast of Randall Blockhouse. (locality 6317).
RS-4 = Miocene strata about 1585 m north and slightly west of NOTS Pier.

MIOCENE SANDSTONE

The base of the Miocene sedimentary sequence is a coarse, poorly-consolidated, unfossiliferous, dark-gray volcanic sandstone overlying rhyolite flow lava. The basal sandstone is best developed at RS-3 (Fig. 6) with a maximum thickness of approximately 1.2 m which thins northward to about 0.3 m at RS-2, within a distance of about 660 m. This basal sandstone was not recognized by Vedder and Moore (1976) from the NOTS Pier area. They reported shale and claystone lying unconformably on the rhyolite.

Grading upward from the basal volcanic sandstone is a prominent marker bed of loosely-consolidated to well-indurated, medium to coarse grained, fossiliferous, orange sandstone. This unit is best exposed at RS-3 (4.5 m thick), where the basal 1.2 m has abundant *Pecten* (*Amussiopecten*) *lompocensis* Arnold (Figs. 12-17). Echinoid spines, rare gastropod nodes similar to those of the genus *Trophon,* marine mammal bones and teeth, shark teeth, and fish bones occur commonly throughout the sandstone. At section RS-4, where the orange sand is approximately 1.5 m thick, only a few diagnostic fragments of *P.* (*A.*) *lompocensis* were found. Other equivalent localities were reported by Olmsted (1958) from the central island area, including his locality F-3 which contains fragments of *Chlamys* (*Lyropecten*) *crassicardo* (Conrad), and his locality F-2 from which he reported "abundant shell fragments, chiefly pectinids, and scattered mammalian bones." Vedder and Moore (1976) reported *Lyropecten crassicardo* (Conrad), *Amussiopecten* cf. *A. vanvlecki* (Arnold), and *Crassostrea* cf. *C. freudenbergi* (Hertlein and Jordan) in equivalent beds from the China Canyon section, USGS loc. M6505.

Near the base of the orange sandstone are dense limestone lenses containing *Ostrea* sp. with other unidentifiable shell fragments. These lenses have been observed on the north wall of the most southerly exposure at RS-3, and near the pier at Wilson Cove. Olmsted (1958) reported limestone at his locality F-3, overlying "gritty andesitic sandstone about 2.5 m thick that in turn overlies a flow of platy-jointed andesite." Calcarenite deposits overlying andesite flow in China Canyon (Vedder and Moore 1976) appear to be similar to limestone lenses at RS-3 and Wilson Cove. Bramlette (1946) established limestone "reef" structures at the base of the Monterey Formation, generally as a boundary between lower and middle Miocene sediments. Similar middle Miocene structures are found locally in the Palos Verdes Hills areas (Bramlette 1946) and in southwestern Orange County (Morton and others 1974).

The authors collected a large, shattered desmostylid tooth (Figs. 27, 28, 29) from a grayish sandstone (loc. 6363) about a meter above beds containing *P.* (*A.*) *lompocensis* and stratigraphically below the silty diatomaceous shale. The tooth was examined by L. G. Barnes, Los Angeles County Museum of Natural History, who suggested that the specimen could be *Paleoparadoxia tabatai,* whose characteristic cingulae have been worn off (personal communication, Mar. 24, 1977).

MIOCENE DIATOMACEOUS SHALE

The diatomaceous shale member is probably the most widespread sedimentary unit within the area investigated. Vedder and others (1975) and Vedder and Moore (1976) have correlated this unit with the middle Miocene Monterey Formation, locally found in the Palos Verdes Hills, San Joaquin Hills, and Capistrano syncline. The representative section is exposed at RS-3 with a thickness of about 18 m and conformably overlying orange sand which becomes finer and grades upward into diatomaceous shale. The shale is interbedded with several layers (about 7 cm thick) of gray, finely laminated chert with abundant fish scales. Above the chert layers, four phosphate nodule layers (each about 2.5 cm thick) are intercalated with the shale. A bluish, unaltered vitric ash layer (15 cm thick) occurs near the top of the unit. Fish remains, shark teeth, and marine mammal bones and teeth are common through the shale.

Elsewhere, the shale extends north and south of NOTS Pier, and is exposed at RS-2. More extensive sections, as much as 90 meters in thickness (Mitchell and Lipps 1965), are exposed on the southern part of the island. Vedder and Moore (1976) extensively examined the Horse Cove and China Canyon diatomaceous deposits, which they suggested resemble parts of the Monterey Shale exposed at Newport Bay and in the Capistrano syncline.

The depositional sequence of orange sand with limestone lenses overlain by diatomaceous shale containing chert, phosphate nodules, and vitric ash layers is equivalent to the depositional sequence of middle Miocene units in the El Toro and San Joaquin Hills area of Orange County (Morton and others 1974; Stadum 1975).

PLIOCENE BIOGENIC SEDIMENTS

The Pliocene bioclastic outcrops appear to be restricted to the eastern flank of the central island region. The basal bed is an unsorted, thin, pebble to cobble conglomerate, composed of volcanic clasts uncomformably overlying the Miocene diatomaceous shale. A complete section, exposed in a small ravine several hundred meters south of RS-1, is approximately 30 m thick. Although the bottom and top contacts are not visible, a better exposed section is in a roadcut to Randall Blockhouse (RS-1) (Fig. 9). Pliocene sediments are also present at Lemon Tank Reservoir (Vedder and Moore 1976) unconformably overlying Miocene sandstone on the northwest wall. Vedder and Moore (1976) collected well-preserved *P. bellus, P. healeyi,* moulds of minute gastropods *Alvania* and *Bittium,* and other fossils from a truncated calcarenite remnant at USGS loc. M6501 at Lemon Tank Reservoir. About one hundred m east of USGS loc. M6501, the authors found mixed Pliocene-Pleistocene sands containing the following species: *Glycymeris* (*Axinola*) *grewingki* Dall, *Cyclocardia* cf. *C. ventricosa* Gould, *Pseudocardium* sp., *Calliostoma* cf. *C. gemmulatum* Carpenter, *Calliostoma* cf. *C. annulatum* Martyn, *Architectonica* cf. *A. nobilis* Röding, *Haliotis* sp., *Opalia* (*O.*) *wroblewskyi* (Mörch), *Terebratalia* cf. *T. occidentalis* Dall, *Laqueus vancouveriensis diegensis* Hertlein and Grant, and *Paracyathus* cf. *P. stearnsii* Verrill.

Biogenic detritus and shells compose 95% of the gently dipping, massive, coarse Pliocene strata. Where firmly cemented, the chalky-colored biolith forms noticeable outcrops with rounded, wave-cut cavities (Fig. 11) greater than a meter in diameter. There are two significant conglomerate beds (Fig. 10), with a thickness of 0.30 to 1.0 M composed of dacite, andesite, and rhyolite clasts.

The poorly-sorted bioclastic sediments are predominantly bryozoans, foraminifers, and echinoid spines. Within this unit, there are four fossiliferous layers containing the Pliocene guide fossil *Pecten* (*P.*) *bellus* (Conrad) and a new subspecies of *Pecten* (*Patinopecten*) *healeyi* Arnold. Other species include *Pecten* cf. *P.* (*P.*) *lecontei* Arnold, *Chlamys* (*C.*) *opuntia* Dall, *Pododesmus macroschisma* Deshayes, *Mytilus* sp., *Anomia peruviana* d'Orbigny, *Hinnites* sp., *Opalia* (*O.*) *varicostata* Stearns, *Epitonium* (*Nitidiscala*) cf. *E.* (*N.*) *indianorum* (Carpenter), and distinctive layers of the brachiopods (Fig. 8) *Laqueus californianus* Koch, *L. vancouveriensis diegensis* Hertlein and Grant, and *Terebratalia hemphilli* Dall. All invertebrates are well-preserved. Brachiopods and pelecypods generally are articulated and faintly retain their original colors.

Although similar assemblages are found in Pliocene marine deposits throughout southern California (Pico Member of the Fernando Formation in the Ventura and Los Angeles Basins; Santa Barbara Formation in the Ventura Basin; "San Diego" Formation in the western Santa Monica Mountains; Fernando Formation in the Palos Verdes Hills and Orange County; and Niguel Formation in the San Joaquin Hills) the lithology and fossils of the San Clemente Island Pliocene strata appear to be most similar to the San Diego Formation in coastal San Diego County. Hertlein and Grant (1944) described the San Diego Formation as deposits containing layers of conglomerates and lacking fine sediments "which indicates a water depth from low tide to possibly fifty fathoms." They also noted the occurrence of pockets, seams, and rare beds of nearly pure white marl in exposures of the San Diego Formation suggesting lithologic similarity to the San Clemente Island Pliocene.

In a more recent report, Hertlein and Grant (1960) listed *Pecten* (*P.*) *bellus, Pecten* (*Patinopecten*) *healeyi, Chlamys* (*C.*) *opuntia, Laqueus californianus, L. vancouveriensis diegensis,* bryozoans, and echinoids from the San Diego Formation exposed at Pacific Beach. The report stated that species of the brachiopod genus *Laqueus* (which is abundant in San Clemente Island Pliocene sediments) "occur at moderate depths on clear sea bottoms free of mud, and a greater number occur in warm rather than cold water." By comparing the similar fauna and lithology of the San Diego Formation with San Clemente Island Pliocene sediments, the authors suggest that the strata were deposited in a clear, sublittoral environment that was slightly warmer than at present.

Olmsted (1958) separated the younger deposits into Older Sand (Pleistocene) and Younger Sand (Recent). He designated the older deposits as chiefly old dunes with beach sand and lagoonal deposits. He stated that the distinction between the flat-lying sandy Miocene beds overlain by older Pleistocene sand deposits "is difficult principally in the large area centered at 7 km south-southeast of Wilson Cove." This large area is the general location of the gently dipping Pliocene bioclastic sediments (RS-1, RS-2), which may be the "flat-lying sandy Miocene beds" mentioned by Olmsted.

PLEISTOCENE MARINE SEDIMENTS

The Pleistocene consists of gray to buff color, fossiliferous sand with a basal conglomerate, that differs in its relationship with underlying beds from locality to locality. At RS-1 (loc. 6320) and RS-2 (loc. 6327), Pleistocene sand unconformably overlies Pliocene sediments; about 800 m west of Wilson Cove and at NOTS Pier, Pleistocene sand is unconformable on Miocene shale (loc. 6326); several hundred m south of Wilson Cove (loc. 6324), it rests unconformably upon volcanic rocks; east of Northwest Harbor near the northeast side of the new airfield, the underlying unit is a volcanic conglomerate of unknown age (loc. 6323). The mollusks, representing a littoral and a sublittoral environment, are found in loosely consolidated sand except at localities 6320, 6324, and 6327, where they occur between and attached to clasts in the basal conglomerate. *Codakia* (*Epilucina*) *californica* (Conrad) was the most commonly collected species from each locality.

The following is a list of Pleistocene fossils collected from six localities. This assemblage can be correlated with the late Pleistocene Palos Verdes Sand fauna of the Los Angeles Basin.

UCLA locality 6320
- *Codakia* (*Epilucina*) *californica* (Conrad)
- *Transenella tantilla* (Gould)
- *Acmaea* (*Acmaea*) *mitra* Eschscholtz
- *Acmaea* (*Collisella*) *scabra* Gould
- *Hipponix tumens* Carpenter

UCLA locality 6323
- *Codakia* (*Epilucina*) *californica* (Conrad)
- *Glans subquadrata* (Carpenter)
- *Acmaea* (*Collisella*) *digitalis* Eschscholtz
- *Acmaea* (*C.*) *pelta nacelloides* Dall
- *Acmaea* (*C.*) *scabra* Gould
- *Acmaea* (*C.*) *scutum* Eschscholtz
- *Fissurella volcano* Reeve
- *Tegula funebralis* (A. Adams)
- *Littorina planaxis* Philippi
- *Hipponix antiquatus* (Linnaeus)
- *Hipponix tumens* Carpenter
- *Serpulorbis squamigerus* (Carpenter)
- *Bittium* sp.
- *Amphissa versiocolor* Dall
- *Fusinus barbarensis* (Trask)
- *Olivella biplicata* (Sowerby)
- *Trimusculus reticulata* (Sowerby)
- *Ischnochiton* sp.

UCLA locality 6324
- *Codakis* (*Epilucina*) *californica* (Conrad)
- *Fissurella volcano* Reeve

  - *Tegula ligulata* Menke
  - *Hipponix antiquatus* (Linnaeus)
  - *Hipponix tumens* Carpenter
  - *Thais* (*Stramonita*) *biserialis* (Blainville)
  - *Mitra idae* Melvill
  - *Hyalina californica* (Tomlin)
  - *Conus californicus* Hinds
- UCLA locality 6325
  - *Codakia* (*Epilucina*) *californica* (Conrad)
  - *Acmaea* (*Collisella*) *limulata* Carpenter
  - *Acmaea* (*C.*) *scabra* Gould
  - *Acmaea* (*C.*) *scutum* Eschscholtz
  - *Haliotis cracherodii* Leach
  - *Megathura crenulata* (Sowerby)
  - *Fissurella volcano* Reeve
  - *Tegula funebralis* (A. Adams)
  - *Norrisia norrisi* (Sowerby)
  - *Littorina planaxis* Philippi
  - *Hipponix antiquatus* Linnaeus
  - *Hipponix tumens* Carpenter
  - *Serpulorbis squamigerus* (Carpenter)
  - *Bursa californica* Hinds
  - *Amphissa versicolor* Dall
  - *Mitra idae* Melville
  - *Hyalina californica* (Tomlin)
  - *Conus californicus* Hinds
- UCLA locality 6326
  - *Codakia* (*Epilucina*) californica (Conrad)
  - *Fissurella volcano* Reeve
  - *Astraea* (*Pomaulax*) *undosa* (Wood)
  - *Tegula funebralis* (A. Adams)
  - *Hipponix tumens* Carpenter
  - *Neverita recluziana* (Deshayes)
  - *Serpulorbis squamigerus* (Carpenter)
  - *Bursa californica* Hinds
  - *Thais* (*Stramonita*) *biserialis* (Blainville)
  - *Mitra idae* Melvill
  - *Olivella biplicata* (Sowerby)
  - *Conus californicus* Hinds
- UCLA locality 6327
  - *Codakia* (*Epilucina*) *californica* (Conrad)
  - *Transenella tantilla* (Gould)
  - *Acmaea* (*Acmaea*) *mitra* Eschscholtz
  - *Acmaea* (*Collisella*) *limatula* Carpenter
  - *Acmaea* (*C.*) *scabra* Gould

Acmaea (C.) scutum Eschscholtz
Fissurella volcano Reeve
Tegula funebralis (A. Adams)
Hipponix antiquatus (Linnaeus)
Mitrella carinata gausapata (Gould)
Thais (*Stramonita*) *biserialis* (Blainville)
Olivella biplicata (Sowerby)
Conus californicus Hinds
Ischnochiton acrior Carpenter

PLEISTOCENE NON-MARINE SEDIMENTS—RECENT DUNE SAND

Loose, wind-blown sand accumulations cover much of the northern half of the island and in many places contain calcareous and siliceous root sheaths or rhizoconcretions (Fig. 5). Johnson (1967) suggested that all the Channel Islands had supported more vegetation during the early Holocene than at the present. The authors found evidence of calcareous root sheaths forming around living sand-dune plants. Opaline silica seams were common within the sand deposits west of NOTS Pier and near the old airfield (Fig. 3). Numerous Indian midden remains and artifacts were observed in the dune sand.

Olmsted (1958) stated that the maximum thickness of the active and recently active sand dunes is approximately 19 meters, and that the older sand deposits are as much as 40 meters thick west of Wilson Cove (loc. 6326).

PALEONTOLOGY

DESCRIPTION OF NEW SUBSPECIES

CLASS BIVALVIA LINNE

ORDER PTERIOIDA NEWELL

FAMILY PECTINIDAE RAFINESQUE

Type (by subsequent designation, Schmidt 1818): *Ostrea maxima* Linne 1758.

Subgenus *Patinopecten* Dall 1898

Type (original designation): *Pecten caurinus* Gould 1850.

Pecten (Patinopecten) healeyi* Arnold *sanclementensis NEW SUBSPECIES

GENUS PECTEN MÜLLER 1776

Diagnosis.—Distinguishable by the much finer and greater number of closely and equally spaced ribs on the left valve; ribs narrow, flat, interspaces shallow and narrow on right valve; right valve gently but evenly convex; left valve slightly convex with anterior and posterior margins flat to somewhat concave; poorly developed ribbing on umbonal area of both valves.

Description.—Shell inequivalve, wider than high, right valve slightly more convex than left valve; *Right valve*—slightly but evenly convex; margins adjacent to ears ornamented by numerous fine radial ribs prior to beginning of primary ribs; approximately thirty, low rectangular, irregular radial ribs separated by narrower, primary shallow interspaces; primary ribs become dichotomus, separated by narrower, extremely shallow secondary interspaces and about twenty percent become trichotomus; primary and secondary interspaces become about equal in width along the outer margin; surface of shell ornamented by numerous, closely spaced fine concentric growth lines becoming more prominent along the margin; hinge line about one-half the shell length; anterior ear slightly longer than the posterior ear; anterior ear separated from body of shell by a narrow, shallow sulcus, a wide fold immediately dorsal to the sulcus, fine radiating lines most prominent adjacent to the dorsal margin of fold, growth lines sinuous; posterior ear with narrow sulcus, numerous fine radiating lines with oblique growth lines. *Left valve*—slightly convex with anterior and posterior margins flat to slightly concave; approximately thirty to thirty-two ribs, low, narrow and sharp, closely but equally spaced; fine secondary riblets occur between primary ribs; shell surface ornamented by minute concentric growth lines which become bundled and prominent along the margin of shell; anterior ear ornamented with fine, slightly sinuous growth lines crossed by radiating lines, a broad shallow sulcus extends from the beak through the middle part of the ear; posterior ear characterized by coarse radiating lines crossed by fine oblique growth lines.

Syntypes.—UCLA Invert. Paleo. Coll. cat. nos. 38790 (right valve), 38791 (left valve).

Locality of Syntypes.—UCLA Invert. Paleo. Coll. loc. no. 6316.

Dimensions of Syntypes.—Right valve - height - 170 mm
- length - 190 mm
Left valve - height - 137 mm
- length - 150 mm

Paratypes.—UCLA Invert. Paleo. Coll. cat. nos. 38792 (right valve), 38793 (left valve).

Locality of Paratypes.—UCLA Invert. Paleo. Coll. loc. no. 6316.

Dimension of Paratypes.—Right valve - height - 148 mm
- length - 172 mm
Left valve - height - 150 mm
- length - 155 mm

Remarks.—Numerous specimens of *P.* (*P.*) *healeyi* from localities throughout southern California were carefully examined. Considerable variation was observed within a given locality, although none are closely similar to the San Clemente Island forms in which the left valve shows a greater range of variation than does the right valve. The variable features of the left valve were also discussed by Vedder and Moore (1976) and they considered that the smooth umbonal form may possibly represent a new species. It is quite reasonable to suspect that the specimens from San Clemente Island may represent an extreme case of maximum variation within the species. However, the specimens from San Clemente Island differ from other described species and display very little variation within the localities, therefore a new subspecies is established. This subspecies is named for San Clemente Island.

PECTEN (*AMUSSIOPECTEN*) *LOMPOCENSIS* Arnold is common in the basal part of the orange sandstone exposed at section RS-3, loc. 6317. Many of the specimens are found articulated, but complete specimens are difficult to collect. Each shell is fractured and it is necessary to coat the surface with an adhesive, prior to removing it from the coarse sandstone matrix.

P. (*A.*) *lompocensis* is often confused with *Pecten* (*Amussiopecten*) *vanvlecki* Arnold, (Arnold 1907) and the two species are not readily separable unless the external and internal surfaces are well preserved. However, there are several helpful distinguishing features, which include the development of the external radial ribs and the spacing of the internal ribs. On the right valve of *P.* (*A.*) *lompocensis,* the external radial ribs are poorly defined and the ribs are paired internally. On the left valve, the external ribs are better developed and the internal ribs are not paired but equally spaced with the interspaces. In *P.* (*A.*) *vanvlecki,* the external ribs on both valves are better developed but internally, the paired ribs occur on the left valve and they are equally spaced in the right valve.

Masuda (1971), in his study of *Amussiopecten,* stated that *P.* (*A.*) *vanvlecki* is easily distinguishable from the frequently confused species *P.* (*A.*) *lompocensis* by ''its rather thick shell, squarish, low, flatly round-topped radial ribs tending to become obsolete towards the ventral and lateral margins, paired internal ribs developed at lower part and larger and angulate auricles.'' Masuda (1971) did not make any distinction as to which valve is characterized by the paired internal ribs.

The occurrence of fragmentary specimens of *Amussiopecten* cf. *A. vanvlecki* is reported by Vedder and Moore (1976) from China Canyon in the southern end of San Clemente Island in association with *Lyropecten crassicardo* (Conrad) and *Crassostrea* cf. *C. freudenbergi* (Hertlein and Jordan), USGS loc. M6505. According to Vedder and Moore (1976), these fossils are imbedded in a fine-to coarse-grained calcarenite which differs considerably in lithology from the orange sandstone in which *P.* (*A.*) *lompocensis* occurs so commonly (UCLA loc. 6317, which apparently has not been visited by previous investigators).

CONCLUSIONS

Unusually well-preserved marine mollusca are found in Neogene sedimentary units on San Clemente Island. Miocene sands contain pecten beds and oyster lenses which suggest a shallow, near-shore environment. Diatomaceous shales, overlying these sands, have been correlated with the coastal Monterey Formation and are evidence of deep submergence during the middle Miocene. These Miocene deposits appear to have accumulated in the same depositional basin as the Monterey Formation in the southeastern Los Angeles Basin and represent a comparable environment.

The overlying Pliocene strata contain abundant brachiopods, bryozoans, and pectens with conglomerate layers which are indicative of shallow water and uplift of the island block. The small fauna includes diagnostic Pliocene species which correlate with the *Pecten* (*P.*) *healeyi* zone (upper Pliocene) throughout southern California.

Abundant collections of Pleistocene littoral and sublittoral mollusks in sand deposits and among volcanic boulders continue to denote elevation of the island. The formation of marine terraces and the deposition of dune sand with rhizoconcretions mark the emergence of the island during the Holocene.

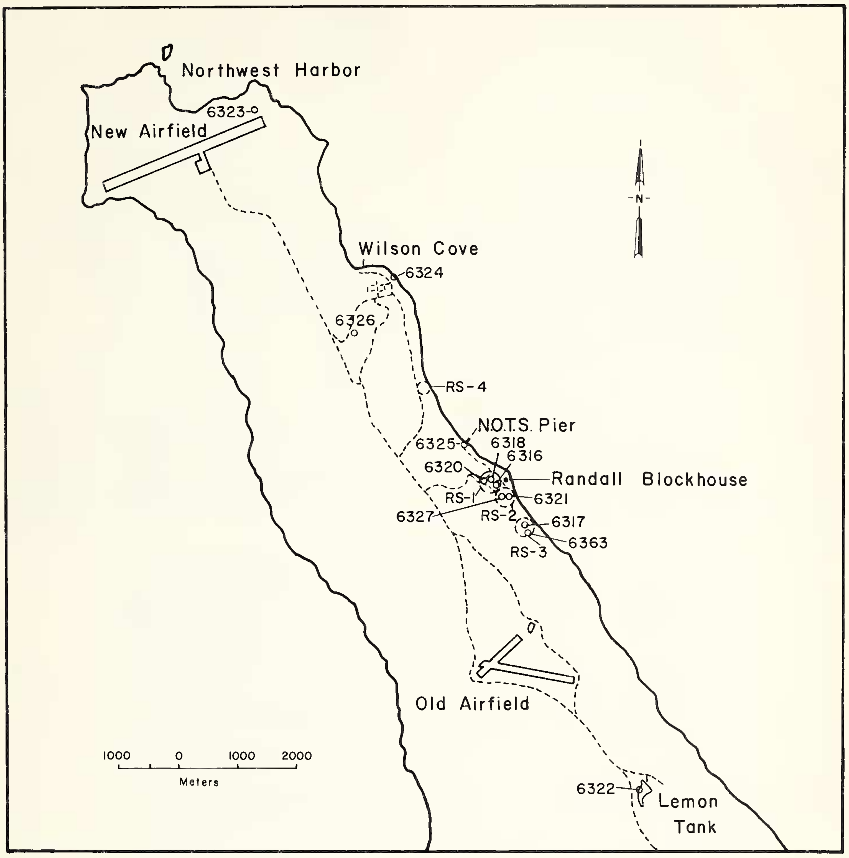


FIGURE 3. Map of northern and part of central San Clemente Island showing fossil localities and RS-sections.

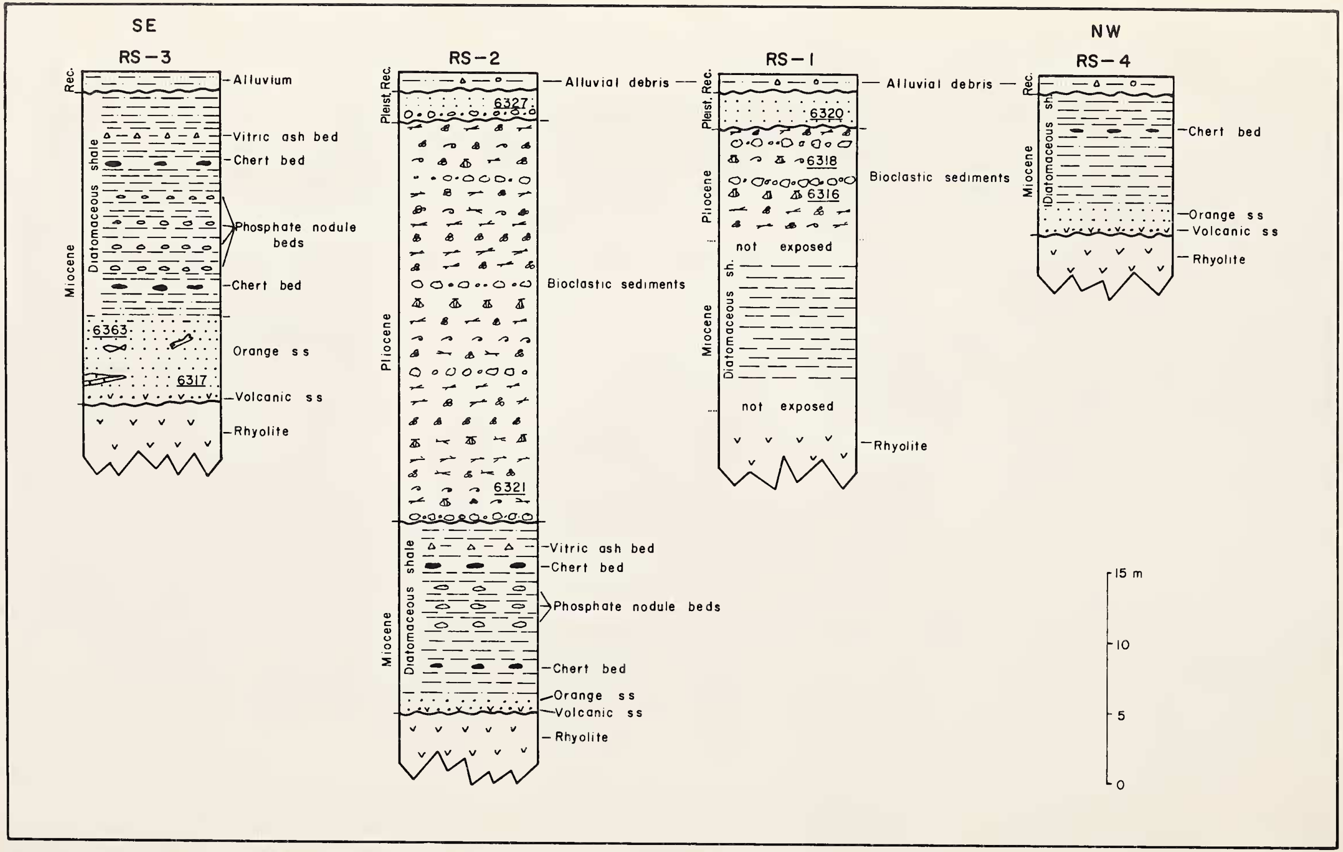


FIGURE 4. A comparison of generalized stratigraphic columns, Randall Blockhouse Area.

5

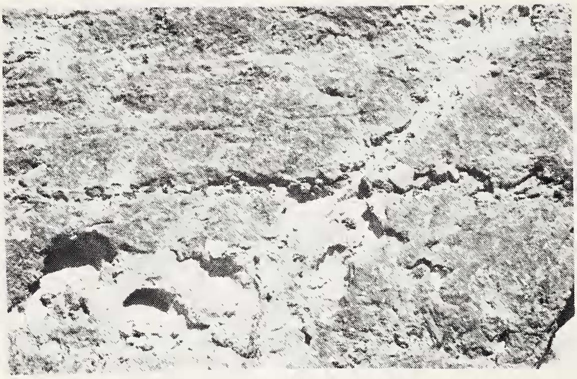
6

7

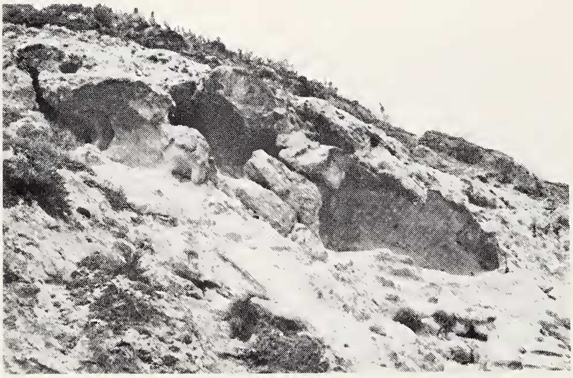
8

FIGURES 5-8. (5.) Rhizoconcretions in post-Pleistocene sands. (6.) Miocene section at RS-3, the darker unit just above the collectors is the orange sandstone. (7.) *Pecten* (*Amussiopecten*) *lompocensis* occurring in the orange sandstone, UCLA loc. 6317. Icepick points to a bone. (8.) Brachiopod bed exposed in roadcut at RS-1.

9

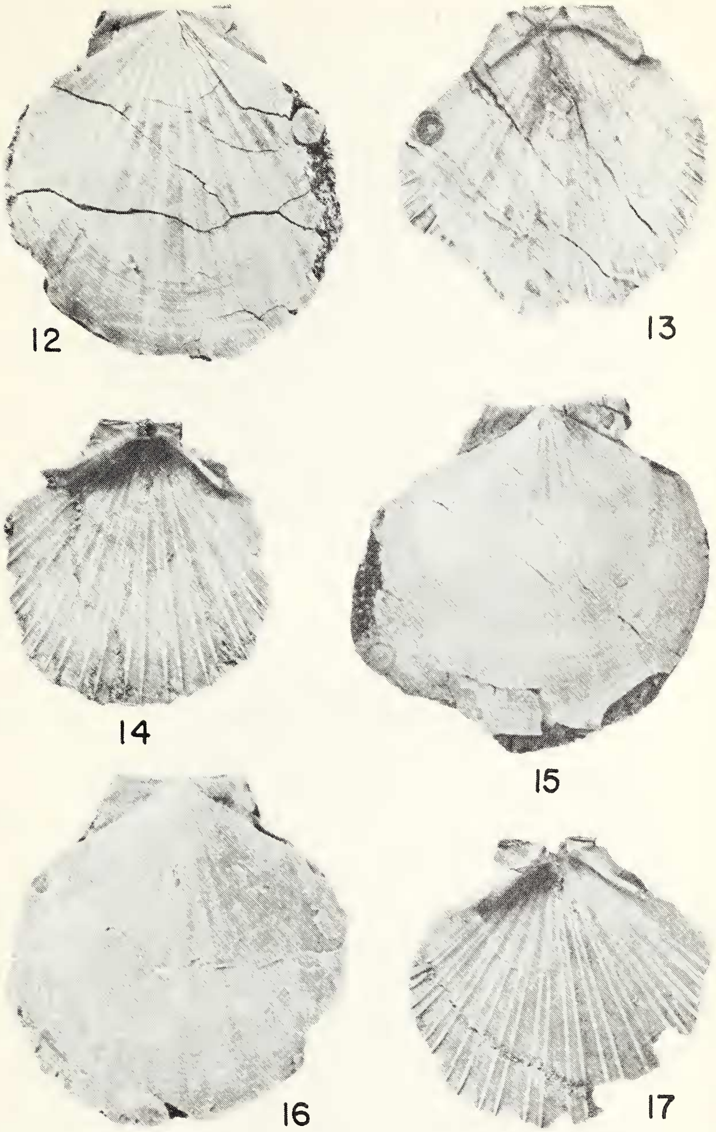


10

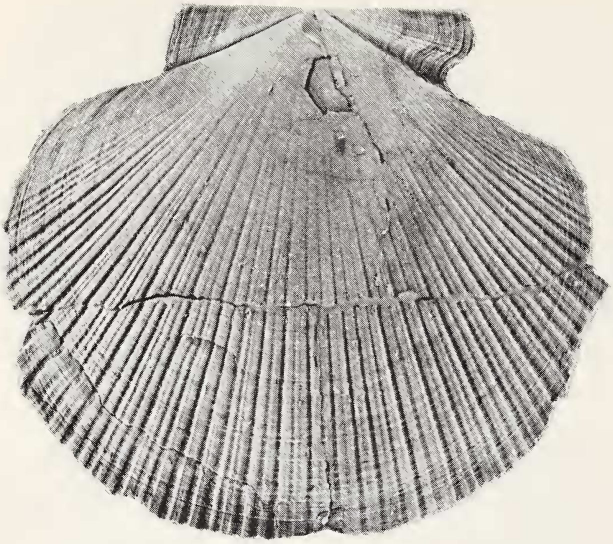


11

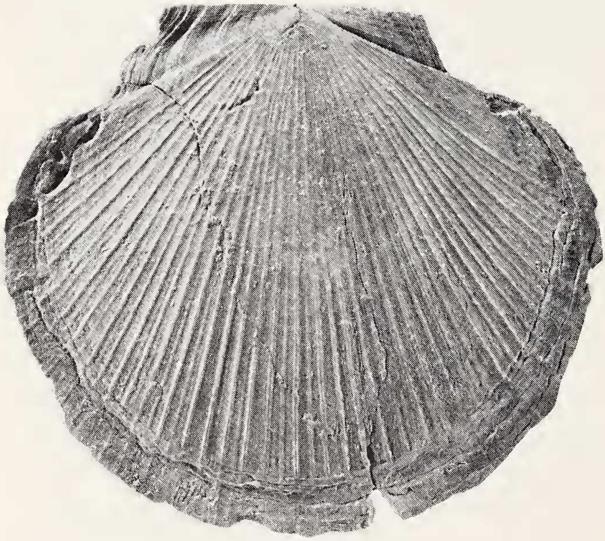
FIGURES 9-11. (9.) Soil-covered Pliocene sediments exposed in roadcut just above Randall Blockhouse, section RS-1. (10.) Characteristic conglomerate layer (middle of photograph) in Pliocene strata. (11.) Rounded, wave-cut cavities in Pliocene strata at RS-2.



FIGURES 12-17. (12.) *Pecten (Amussiopecten) lompocensis* Arnold. left valve. external view. height - 64 mm. length - 64 mm. UCLA cat no. 38788. UCLA loc. 6317. (approx. × 7/10). (13.) *Pecten (Amussiopecten) lompocensis* Arnold. left valve. internal view. height - 70 mm. length - 70 mm. UCLA cat no. 38896. UCLA loc. 6317. (approx. × 3/5). (14.) *Pecten (Amussiopecten) lompocensis* Arnold. right valve. internal view. height - 44 mm. length - 41 mm. UCLA cat no. 38895. UCLA loc. 6317. (approx. × 4/5). (15). *Pecten (Amussiopecten) lompocensis* Arnold. right valve. external view. height - 95 mm. length - 100 mm. UCLA cat no. 38789, UCLA loc. 6317. (approx. × 1/2). (16.) *Pecten (Amussiopecten) lompocensis* Arnold. right valve. external view. height - 64 mm. length - 64 mm. UCLA cat no. 38788. UCLA loc. 6317. (approx. × 7/10). (17.) *Pecten (Amussiopecten) lompocensis* Arnold. right valve. internal view. height - 44 mm. length - 47 mm. UCLA cat no. 38897. UCLA loc. 6317. (approx. × 4/5).

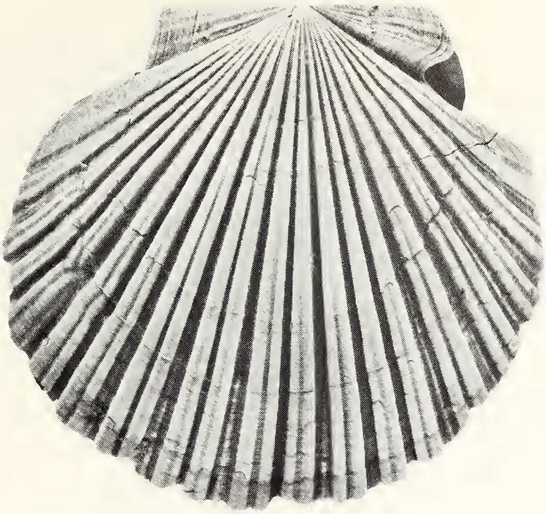


18

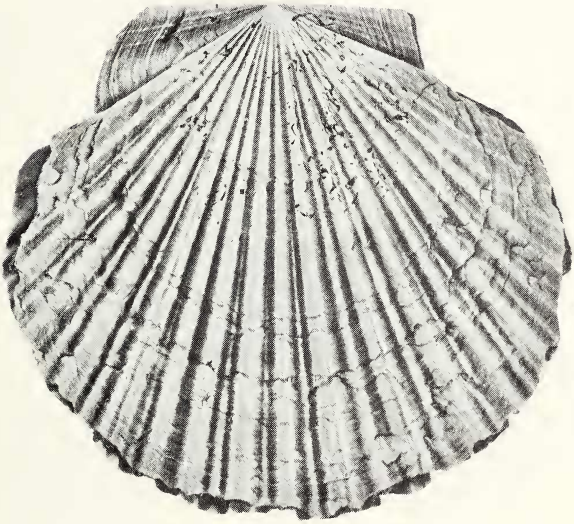


19

FIGURES 18-19. (18.) *Pecten* (*Patinopecten*) *healeyi sanclementensis* n. subsp. Syntype. right valve. height - 170 mm. length - 190 mm. UCLA cat no. 38790. UCLA loc. 6316. (approx. × 2/5). (19.) *Pecten* (*Patinopecten*) *healeyi sanclementensis* n. subsp. Syntype. left valve. height - 137 mm. length - 150 mm. UCLA cat no. 38791. UCLA loc. 6316. (approx. × ½).

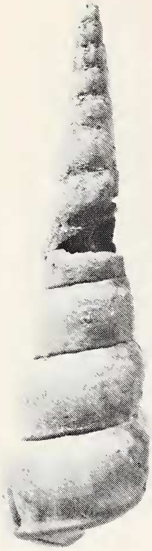


20

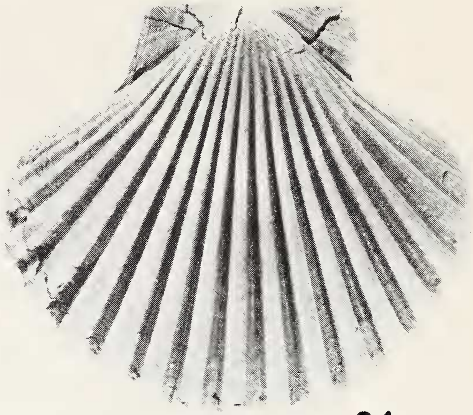


21

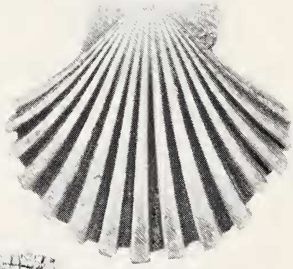
FIGURES 20-21. (20.) *Pecten (Patinopecten) healeyi* Arnold. Hypotype. right valve. Figured by Hertlein & Grant. 1972 (text-fig. 9A, p. 184). height - 122 mm. length - 130 mm. UCLA cat no. 1950. Pacific Beach, San Diego, California (approx. × ½) compare with fig. 18. (21.) *Pecten (Patinopecten) healeyi* Arnold. Hypotype. left valve. Figured by Hertlein & Grant. 1972 (text-fig. 9B, p. 184). height - 122 mm. length - 130 mm. UCLA cat no. 1950. Pacific Beach, San Diego, California. (approx. × ½) compare with fig. 19.



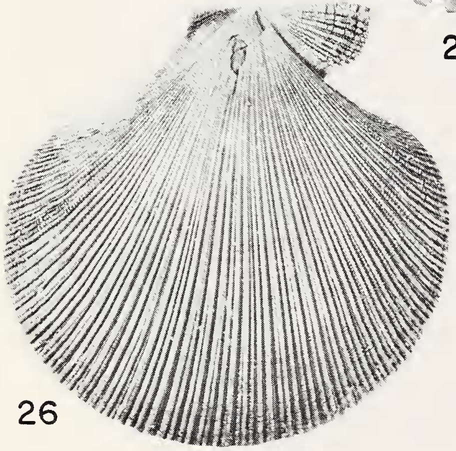
22



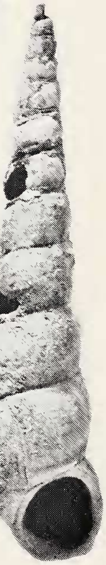
24



25

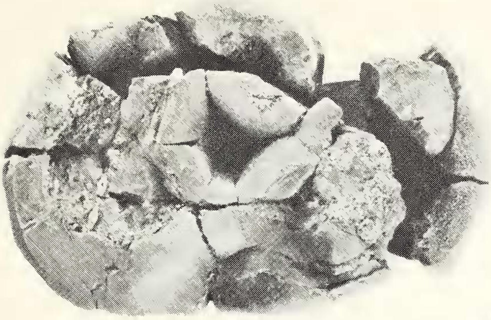


26



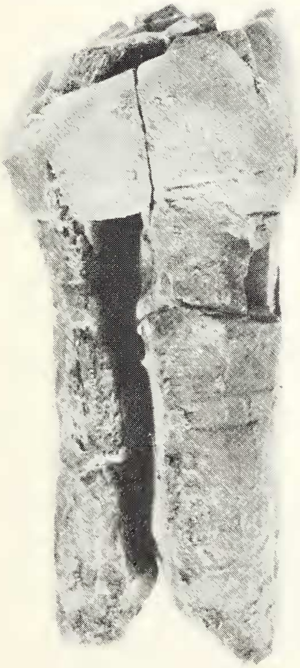
23

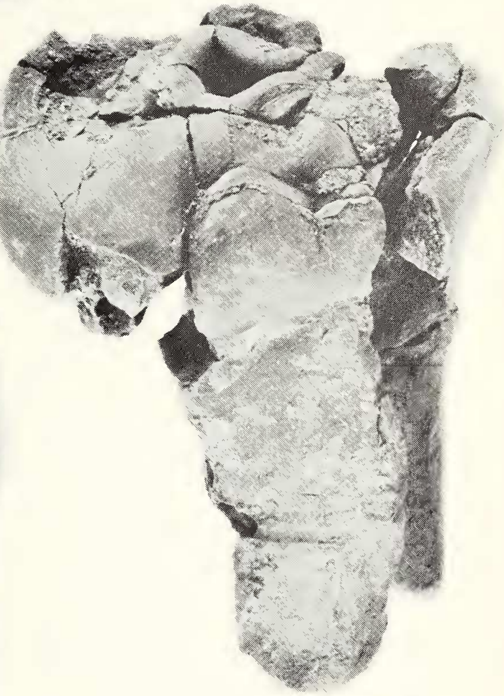
FIGURES 22-26. (22.) *Opalia (Opalia) wroblewskyi* (Mörch). ab-aperture view. height - 81 mm. width - 22 mm. UCLA cat no. 38798. UCLA loc. 6322. (approx. × 9/10). (23.) Same specimen as fig. 22. aperture view. (approx. × 9/10). (24.) *Pecten (Pecten)* cf. *P. (P.) lecontei* Arnold, right valve. height - 60 mm. length - 67 mm. UCLA cat no. 38787. UCLA loc. 6316. (approx. × 9/10). (25.) *Pecten (Pecten) bellus* (Conrad). right valve. height - 39 mm. length - 43 mm. UCLA cat no. 38786. UCLA loc. 6316. (approx. × 9/10). (26.) *Chlamys (Chlamys) opuntia* (Dall). right valve. height - 66 mm. length - 66 mm. UCLA cat no. 38797. UCLA loc. 6316. (approx. × 9/10).



27

28





29

FIGURES 27-29. (27.) Large desmostylid tooth. occlusal view. UCLA cat no. 57531. UCLA loc. 6363. (approx. × 2) length - 33 mm. width - 22 mm. (28.) Same specimen as fig. 27. end view. (approx. × 2) height - 44 mm. (29.) Same specimen as fig. 27. labial view. (approx. × 2).

ACKNOWLEDGMENTS

The authors are indebted to Herb Beltran, Foreman Rigger, Naval Undersea Center (NUC), San Clemente Island, who arranged for the initial visit to the island and provided invaluable aid in camp and in the field. Jack Harris, Range Engineer NUC, arranged for subsequent visits to the island. Those, who were responsible for permitting research to be conducted on the island are Lt. Commander W. G. Kay, Officer-in-charge, San Clemente Island, NUC; Commander Timothy C. Kelley, CEC USN, Public Works Officer, NUC; and Jan K. Larsen, Wildlife Biologist, Natural Resources Program, NUC.

The following people contributed significantly in the field: Carl Westendarp, NUC; Marvin Rohrs and Lorna Ross, Natural History Foundation of Orange County; Mark Beck, Bill and John Beltran, Danny Cook, Richard Ebel, Alan Leach, John Lerno, Lorry Partridge, Cindy Phelps, and Roger Zachery, Huntington Beach High School. Lawrence G. Barnes, Earth Science Division, Los Angeles County Museum of Natural History examined the desmostylid tooth. The manuscript was kindly read and criticized by Willis P. Popenoe and Paul M. Merifield, Department of Geology, University of California, Los Angeles. Recognition is given to Edward C. Wilson, Earth Science Division, Los Angeles County Museum of Natural History, Warren O. Addicott, Department of Paleontology and Stratigraphy, United States Geological Survey, Menlo Park, California, and Jere H. Lipps, Department of Geology, University of California, Davis, California for their critical review.

All illustrations and photographs were prepared by the authors.

FOSSIL LOCALITY REGISTER

The following locality numbers are those of the paleontology collection, Department of Geology, University of California, Los Angeles. They all were plotted on the U.S. Geological Survey topographic quadrangle of San Clemente Island North (7.5 min., 1950), unless otherwise indicated.

6316 - Sediments containing *Pecten* (*P.*) *bellus* and *Pecten* (*P.*) *healeyi sanclementensis* n. subsp. exposed in both sides of a roadcut, just before last turn to the end of road to Randall Blockhouse (RS-1), approx. 792 m S 42° E of NOTS Pier. (Upper Pliocene).

6317 - Loosely consolidated orange sandstone bed containing *Pecten* (*A.*) *lompocensis* exposed in a narrow, steep canyon approx. 1524 m S 35° E of NOTS Pier and about 1097 m N 58° E of BM-820 (RS-3). (Middle Miocene)

6318 - Well-indurated chalky-colored sediments cropping out on the south side of a narrow ravine containing *Pecten* (*P.*) *bellus,* about 213 m west of Randall Blockhouse (RS-1), (Upper Pliocene)

6320 - Pleistocene fossils attached to boulders and in the sand between the conglomerate on the southside of a narrow ridge about 427 m S 13° W of Randall Blockhouse (RS-1) and approx. 700 m S 18° W of NOTS Pier. (Upper Pleistocene)

6321 - Steep, small gully south of Randall Blockhouse (RS-2), Pliocene section exposed unconformably overlying Miocene shale and underlying Pleistocene conglomerate, about 213 m south of Randall Blockhouse. (Upper Pliocene)

6322 - Fossils collected from disturbed (by grading) beds overlying the brownish-orange sandstone on the northwest wall of Canyon (Lemon Tank) just below the top, 365 m east of

Hill 1185, U.S. Geological Survey topographic guadrangle of San Clemente Island Central (7.5 min., 1950). (Upper Pliocene with some Upper Pleistocene)

6323 - Fossils collected from north of northeast end of new airfield, halfway down the slope between upper road to the first wide, flat terrace, 1280 m S 3° E of stream entering Northwest Harbor. (Upper Pleistocene)

6324 - Pleistocene along the top edge of sea wall in conglomerate, overlying volcanic rocks, about 455 m S 65° E from the end of Wilson Cove Pier. (Upper Pleistocene)

6325 - Pleistocene fossils in conglomerate and loose sand overlying Miocene shale, directly behind building by NOTS Pier. (Upper Pleistocene)

6326 - Fossiliferous Pleistocene bed in a shallow cut, lying unconformably on Miocene shale, 365 m S 68° E of Harbor triangulation station 648. (Upper Pleistocene)

6327 - Pleistocene fossils in conglomerate unconformably overlying Pliocene sediments in a gully 183 m due south of Randall Blockhouse (RS-2). (Upper Pleistocene)

6363 - A large desmostylid tooth collected from a gray sandstone approximately one hundred m south of UCLA loc. 6317, stratigraphically about a meter above beds containing *Pecten* (*Amussiopecten*) *lompocensis*.

LITERATURE CITED

ARNOLD, RALPH. 1906. Tertiary and Quaternary pectens of California. U.S. Geol. Surv. Prof. Paper 47: 92–93; pl. 28, figs. 1, 2, 3.

________. 1907, Fossil mollusks from California. Smithsonian Misc. Coll. 50: 428–429; pl. LIII, fig. 1, 2.

BRAMLETTE, M. N. 1946. Monterey Formation of California and the origin of its siliceous rocks. U.S. Geol. Surv. Prof. Paper 212: 55 p.

COOPER, J. G. 1865. Geology of California, Sect. V. Islands off the coast of southern California. Geol. Surv. of California. 1: 182–186.

HERTLEIN, L. G. AND U. S. GRANT. 1944. The geology and paleontology of the marine Pliocene of San Diego, California. Part I. Geology, San Diego Soc. Natur. Hist. Mem. II: 72 p.

________. 1960. The geology and paleontology of the marine Pliocene of San Diego, California. Part 2a. Paleontology. San Diego Soc. Natur. Hist. Mem. II: 73–133; pls. 19–26.

________. 1972. The geology and paleontology of the marine Pliocene of San Diego, California. (Paleontology: Pelecypoda). San Diego Soc. Natur. Hist. Mem. II. Part 2b: 143–409; pls. 27–57.

JOHNSON, D. L. 1967. Caliche on the Channel Islands. California Div. Mines & Geol. 20 (2): 151–158.

LAWSON, A. C. 1893. The post-Pliocene diastrophism of the coast of southern California. Bull. Dep. Geol. Univ. California 1 (4): 135–139.

MASUDA, KOICHIRO. 1971. *Amussiopecten* from North America and northern South America. Palaeontological Soc. Japan Trans. and Proc. 84: 205–224: pls. 25, 26.

MERIFIELD, P. M., D. L. LAMAR AND M. L. STOUT. 1971. Geology of central San Clemente Island, California. Geol. Soc. Amer. Bull. 82 (7): 1989–1994.

MITCHELL, EDWARD D., JR. AND JERE H. LIPPS. 1965. Fossil collection San Clemente Island. Pacific Discovery. 18 (3): 2–8.

MORTON, PAUL K., WILLIAM J. EDGINGTON AND DONALD L. FIFE. 1974. Geology and engineering geologic aspects of the San Juan Capistrano Quadrangle, Orange County, California. California Div. Mines & Geol. Spec. Rep. 112: 12, 48–49.

OLMSTED, F. H. 1958. Geologic reconnaissance of San Clemente Island, U.S. Geol. Surv. Bull. 1071–B: 55–68.

RIDLON, J. B. 1968. San Clemente Island Rocksite Project. Offshore Geology. Part 1. Detailed survey off Eel and Lost Points area. Dep. of the Navy, Naval Weapons Center, China Lake, California: 79 p.

———. 1969. San Clemente Island Rocksite Project. Offshore Geology. Part II. Reconnaissance survey around the island. Dep. of the Navy Weapons Center, China Lake, California: 132 p.

———. 1972. Pleistocene-Holocene deformation of the San Clemente Island crustal block, California. Geol. Soc. Amer. Bull. 83 (6): 1831–1844.

SMITH, W. S. T. 1898. A geological sketch of the San Clemente Island, U.S. Geol. Surv. 18th Ann. Rep. Part 2: 459–496.

STADUM, CAROL J. 1975. ''Paleontological Sites'' Construction of regional wastewater facilities, Environmental Impact Report for Aliso Water Management Agency. Culp/Wesner/Culp, Clean Water Consultants: III-13-19.

STADUM, CAROL J. AND TAKEO SUSUKI. 1976. The discovery of marine Pliocene strata on San Clemente Island, California. Geol. Soc. Amer. Abstracts with programs. 8 (3): 411; Feb. 1976.

VEDDER, J. G., L. A. BEYER, A. JUNGER, G. W. MOORE, A. E. ROBERTS, J. C. TAYLOR AND H. C. WAGNER. 1975. Preliminary report on the geology of the continental borderlands of southern California, U.S. Geol. Surv. Map MF-624: 9 maps.

VEDDER, J. G. AND ELLEN J. MOORE. 1976. Paleoenvironmental implications of fossiliferous Miocene and Pliocene strata on San Clemente Island, California: p. 107–135. *In* D. G. Howell ed. Aspects of the geologic history of the California continental borderland. Pacific Section A.A.P.G. Misc. Pub. 24.

WEAVER, D. W. AND G. L. MYER. 1969. Stratigraphy of northeastern Santa Cruz Island, p. 158–172. *In* D. W. Weaver and others. Geology of the northern Channel Islands, southern California borderland. (Los Angeles, California) A.A.P.G. & S.E.P.M. Pacific Section.

Accepted for publication March 30, 1977.